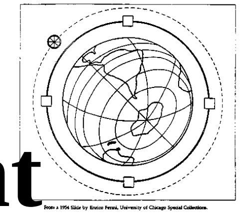
FNAL Common Coil development



G. Ambrosio, N. Andreev, E. Barzi, P. Bauer, K. Ewald, S-W Kim,
P. Limon, I. Novitski, J. Ozelis, G. Sabbi, A. Zlobin *Fermilab*

D. Dietderich, S. Gourlay, R. Scanlan *LBNL*

A. Ghosh, W. Sampson *BNL*

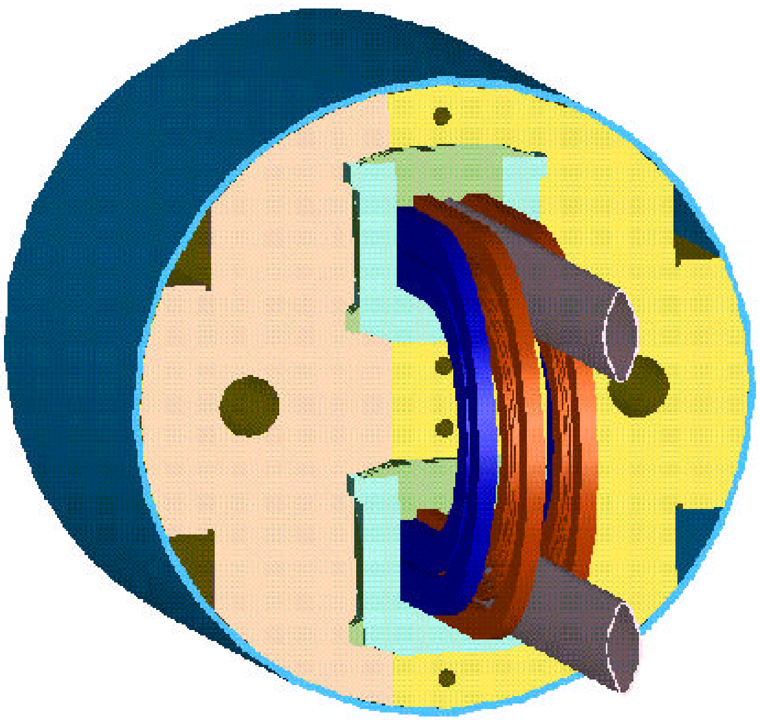
A. Ijspeert *CERN*

Outline:

- Main features,
- Mechanical design,
- Conductor development,
- Practice coils,
- Plans.

VLHC Magnet Workshop
May 24-26, 2000

Hybrid Common Coil



- -Field: Bmax=11 T @ 4.3 K
- -Current: 15.4 kA
- -Good field region: $\Delta B/B<10^{-4}$ @ ϕ<1cm
- -Design: two-layer block type
  two-bore common coil
- -Hybrid: NbSn - NbTi
- -Horizontal bore gap: 30 mm
- -Coil cross-section per bore 11+16 cm^2
- -Strand: Nb_3Sn, ϕ 0.7 mm,
  Jc = 2kA/mm^2 -10% @ 12T, 4.2K
- -Cable: N=40, 1.18*15.0 mm^2 (rect.)
- -Insulation: E-glass tape and Kapton
- -React & Wind technique for NbSn
- -Fermilab/LBNL/BNL collaboration

Hybrid Common Coil

Cost saving magnet

- Hybrid design:

  ==> reduce the use of Nb3Sn,

- React and wind:

  ==> use E glass tape (cheaper and thinner than S2 glass),

  ==> use materials and assembling procedures to reduce costs,

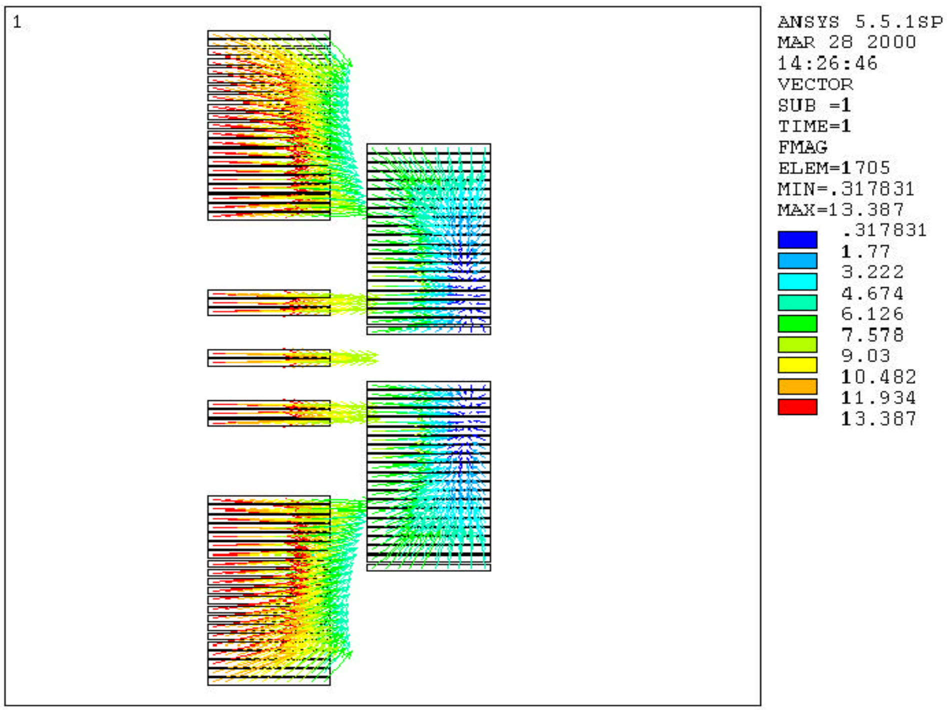
- No auxiliary coils:

  ==> simple assembling and mechanical design.

Mechanical design

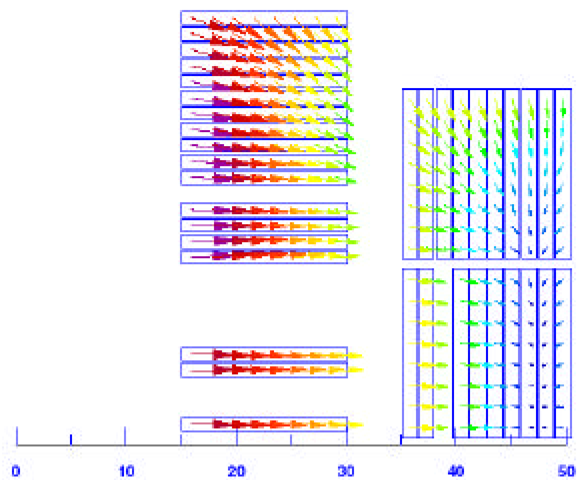
Total magnetic force on 1 quadrant of an aperture @ 11 T

	In.	Out.
Fx (MN/m)	2.2	0.6
Fy (MN/m)	0.4	0.4

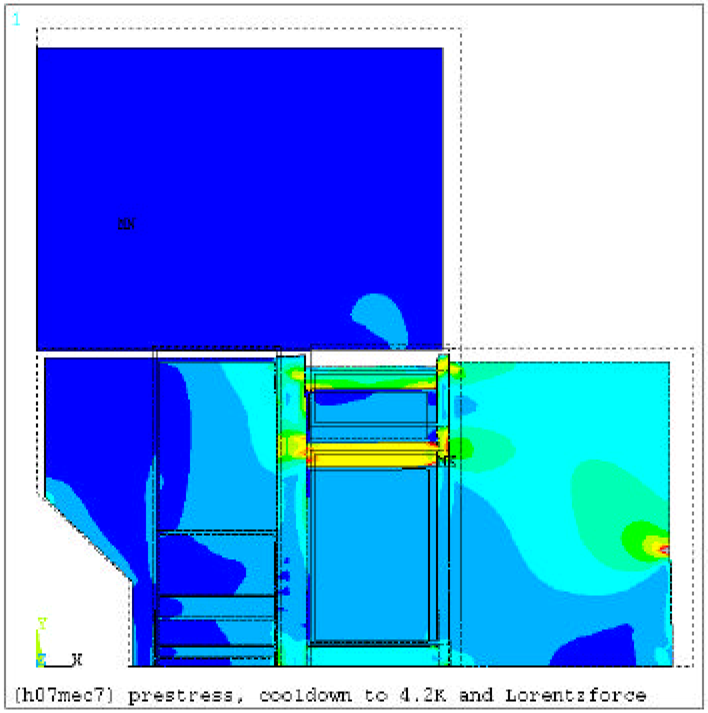


Magnetic forces @ 11 T

"Hard bent outer coil" improve mech. stability against forces from the inner coil



Mechanical analysis of the coil-package

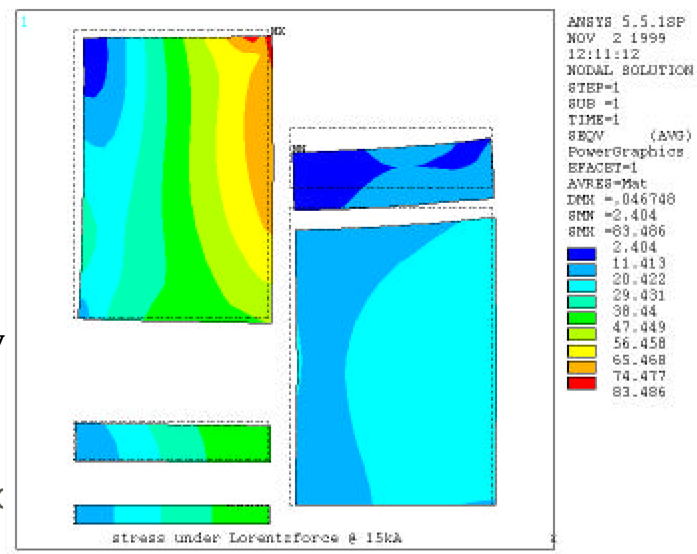


FE-simulation of optimized coil-package at operating conditions. See outer coil protection scheme at work.

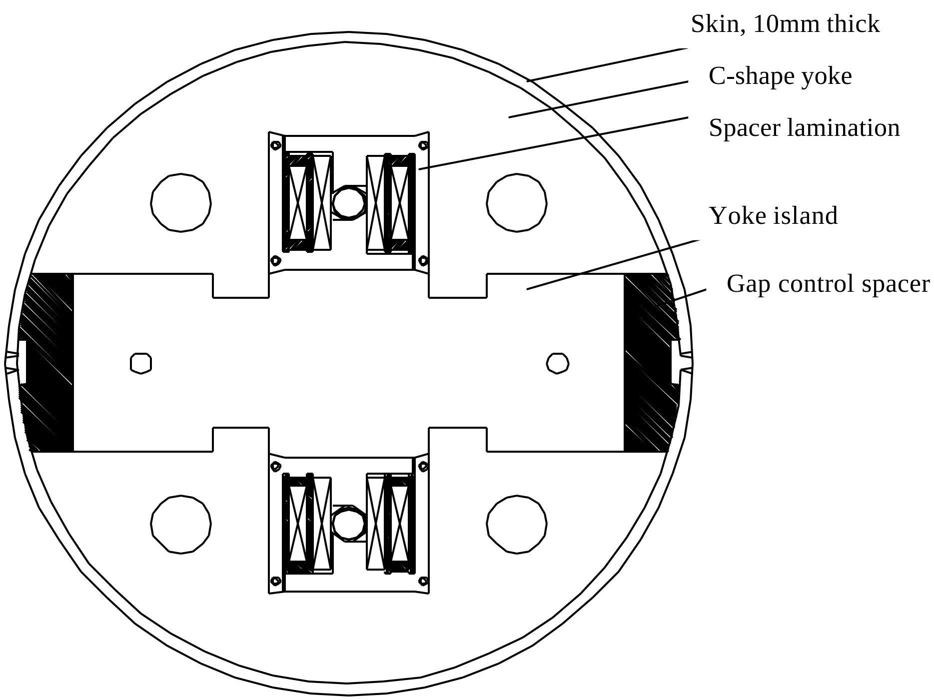
Conclusion:

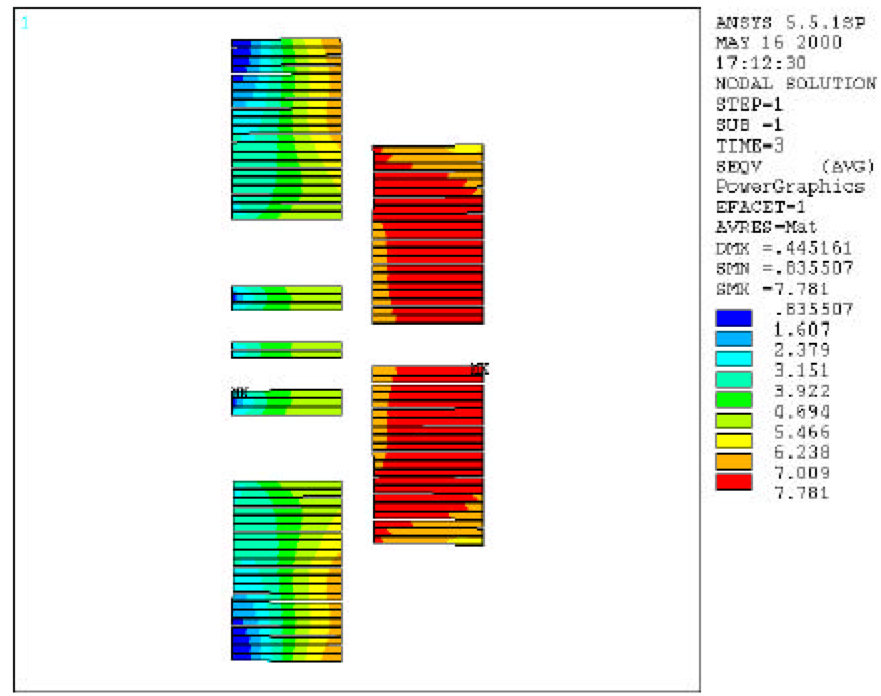
- **outer coil protection scheme: interlayer sheet (steel, > 3 mm), outer coil spacers (Cu, > 3 mm)**
- **measures to prevent coil bending: coils of equal height,**
- **vertical pre-stress, mainly in the outer coil (~ 50 MPa)**
- **horizontal pre-stress, mainly in the upper part of the inner coil (~ 60 MPa)**
- **rigid yoke**

Lorentz forces reacted by infinitely rigid coil boundaries



Mechanical design

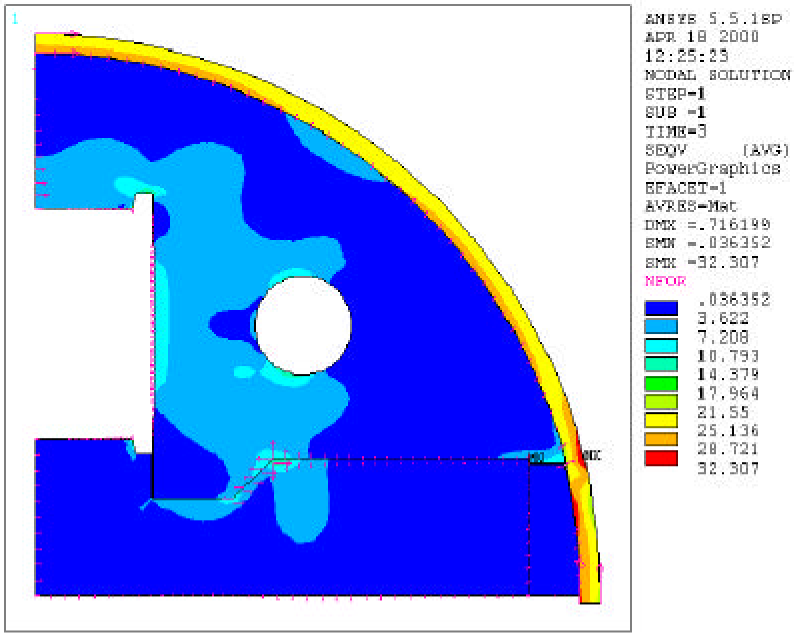




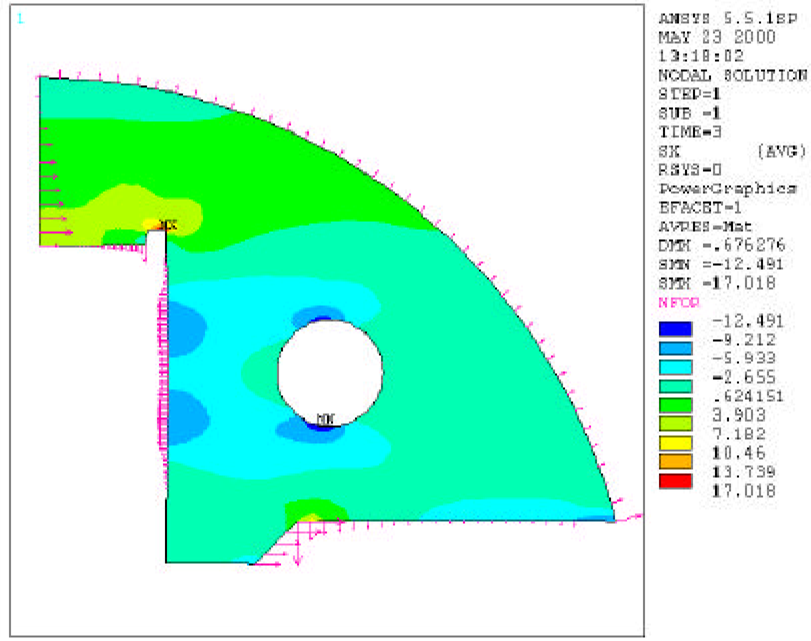
Coils under magnetic forces (stress in Kg/mm²)

	Maximum Equivalent Stress (MPa)		
	after welding	4.2 K	Max field
Inner coil	43	120	72
Outer coil	60	50	78

Mechanical design



Equivalent stress at 11 T (Kg/mm^2)

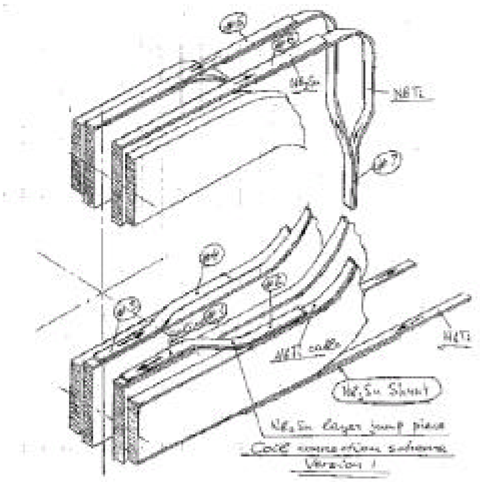


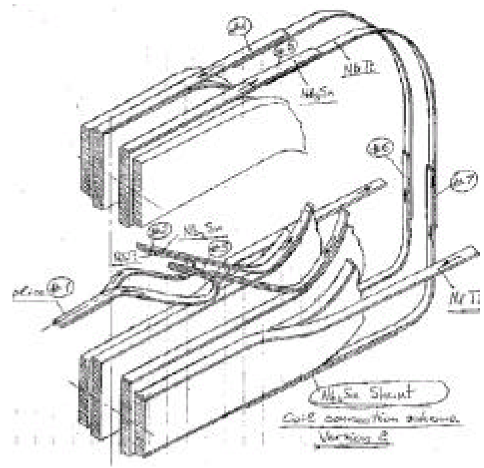
Horizontal stress in the yoke at 11 T (Kg/mm^2)

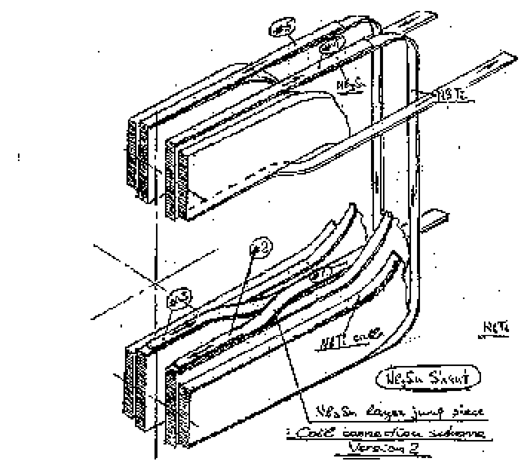
Seqv, MPa	11 tesla
Spacer lamination	145
C-Yoke/Yoke island	180/157
skin	335

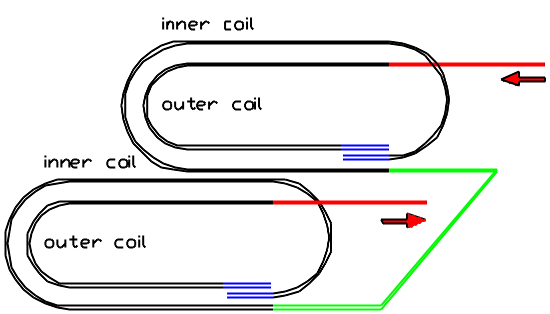
Max tensile stress in iron yoke is 170 MPa. Rounded shape and further optimization should reduce it lower than 140 MPa.

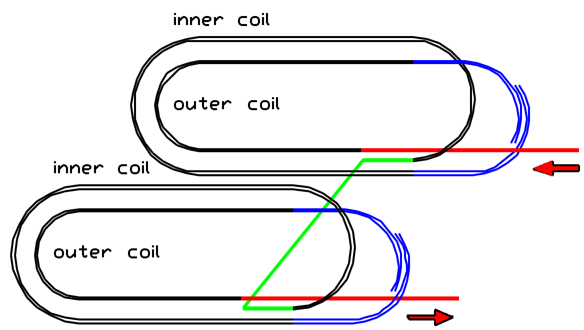
Connection schemes

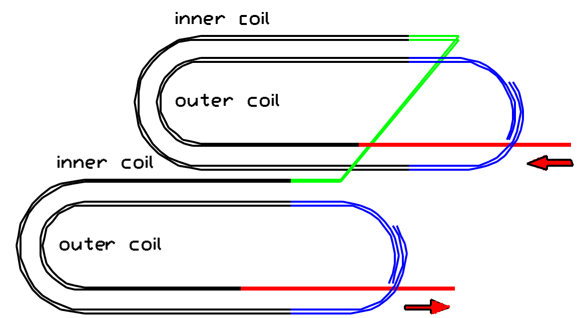












Mechanical design

Alternative mechanical designs under development:

- **Yoke with vertical gaps**

  + modular coils,

  + simple assembling,

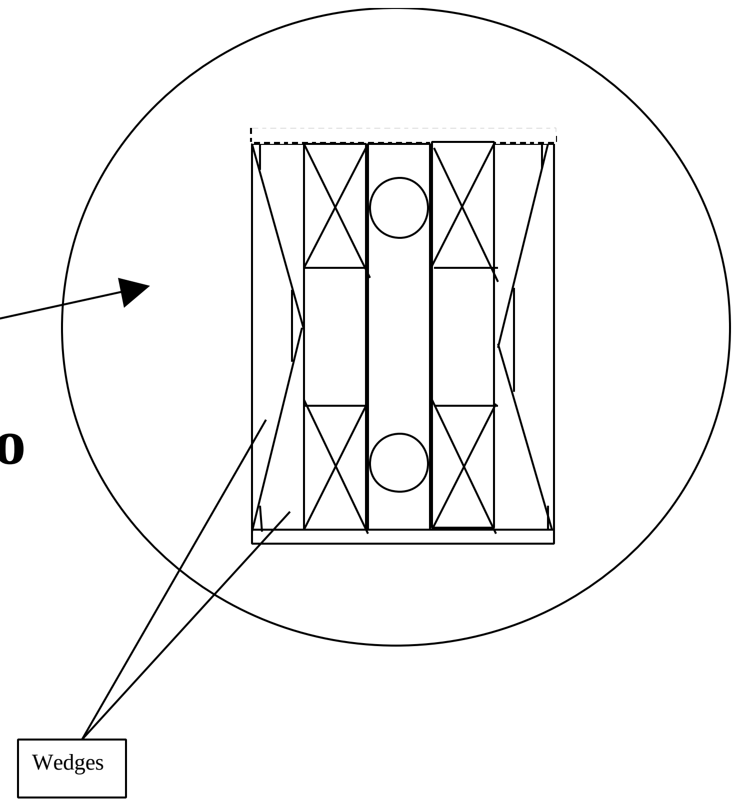
  - requires thick skin,

  - coil motion ?

- **Scissors laminations with wedges to compensate thermal contraction**

  + modular coils,

  - tensile stress in the iron.



Conductor development

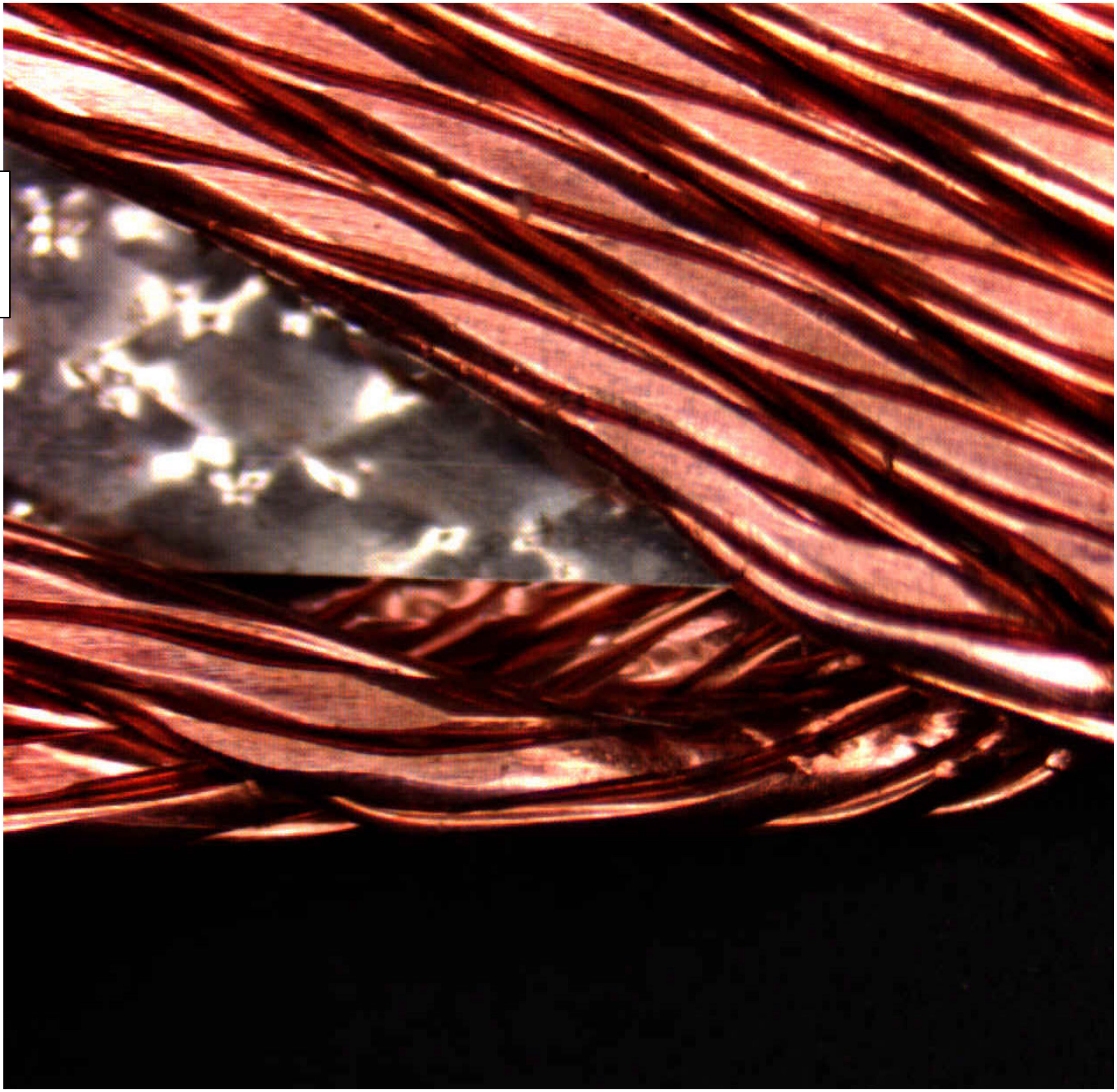
GOALS:

- Optimization of cable design, cabling and reaction procedure
  - ITER wires, different cable designs
- Choice of conductor (ITD, MJR, PIT)
  - short sample bending degradation tests.

Cable	Wire diam. mm	Subel.	No. of strands	Width mm	Thickness* mm	Cable degr. @ 12 T w-w/o core
A	0.5	-	57	15.0	0.85	5% -
B	0.7	-	41	15.0	1.22	7%-7%
C	0.3	6+1	36	15.0	1.51	

* Does not include stainless steel foil (0.025 or 0.013 mm thick)

Detail of cable broad face open to show the core



Strand: ϕ = 0.3 mm

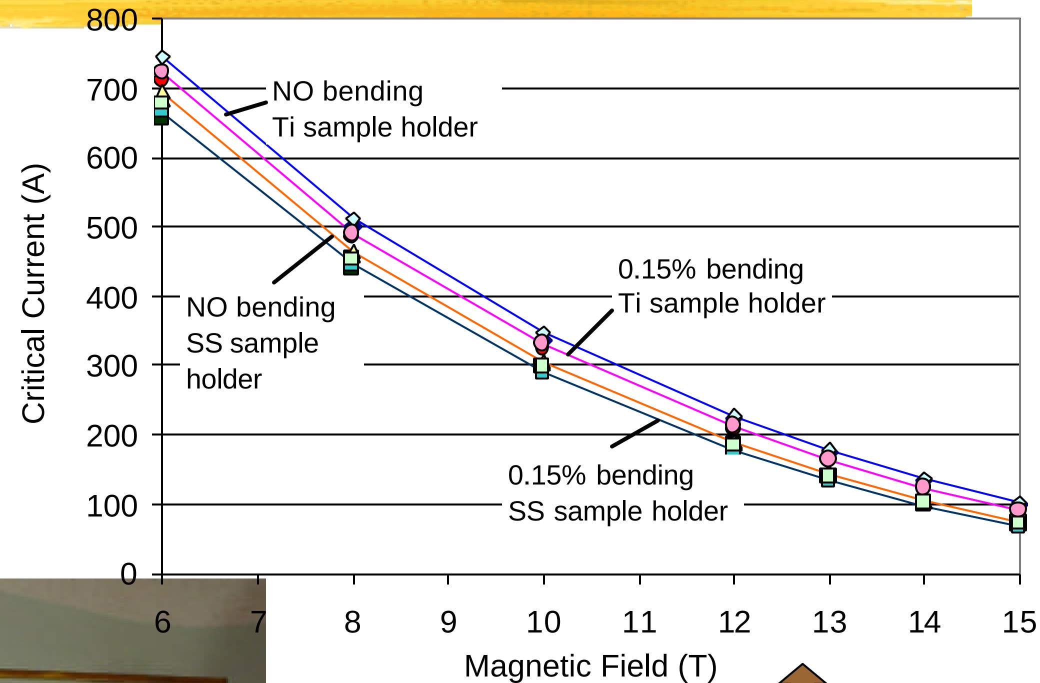
Subelement : 6*1

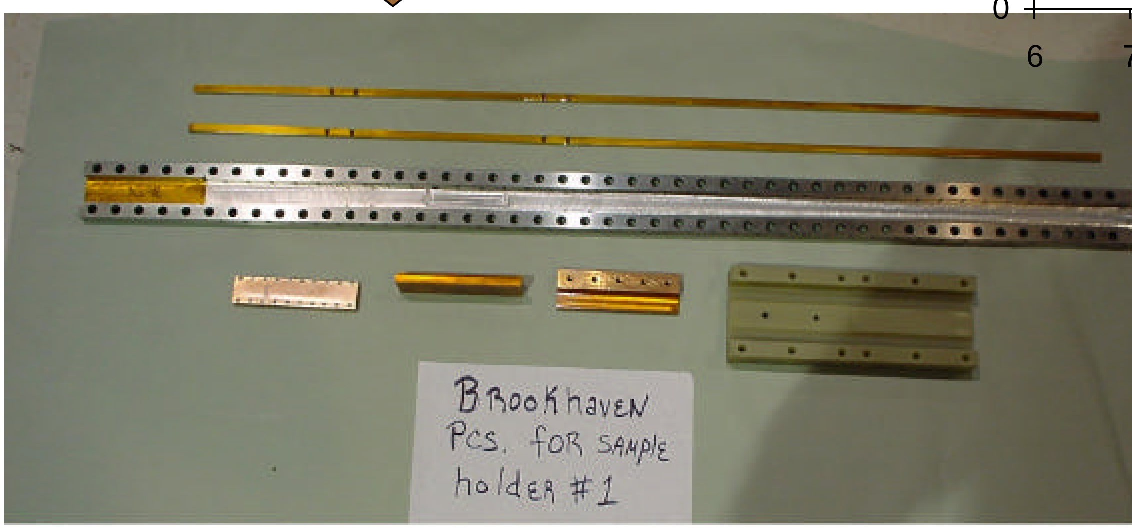
Cable: 36 subelem.
15 x 1.5 mm

Core: 0.013 mm

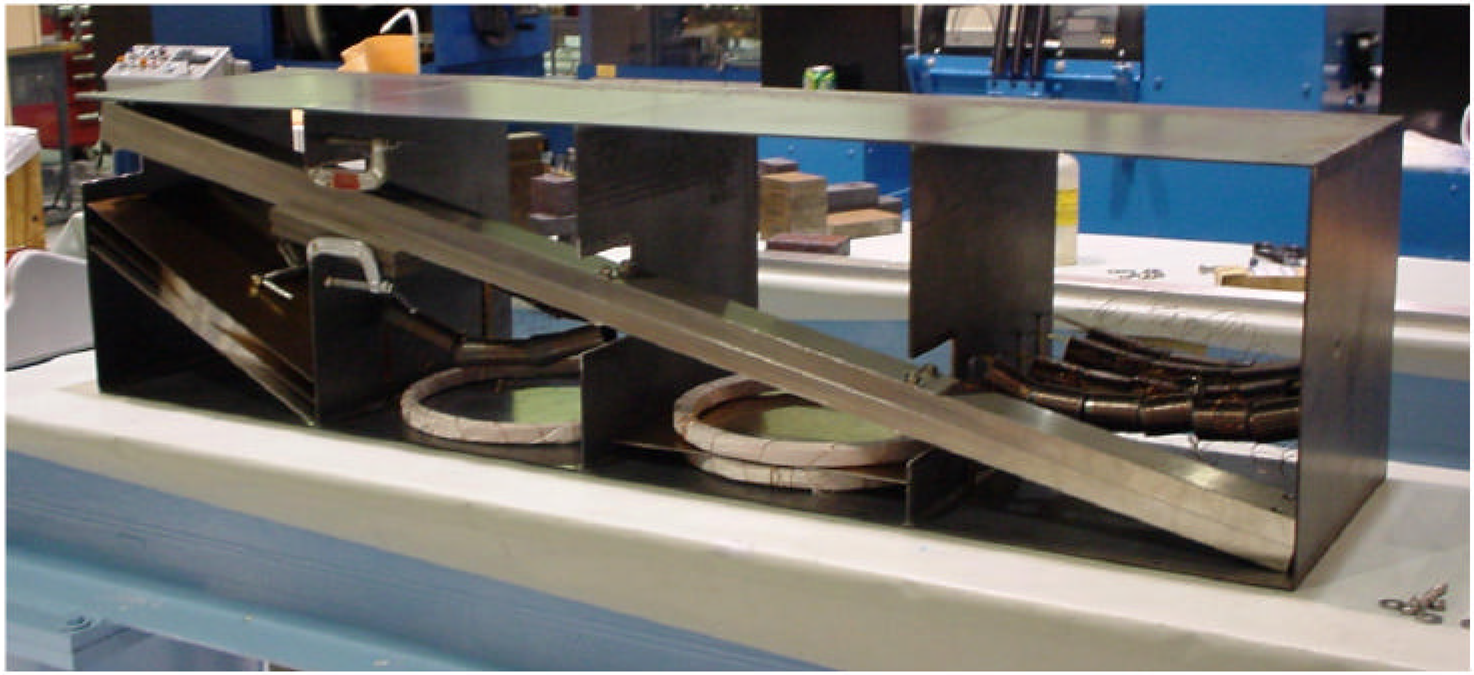
Conductor tests

- Cables:
  - Samples reacted straight and bent,
  - Sample holder can be used both at BNL and at NHMFL,
  - first measurement: June 00

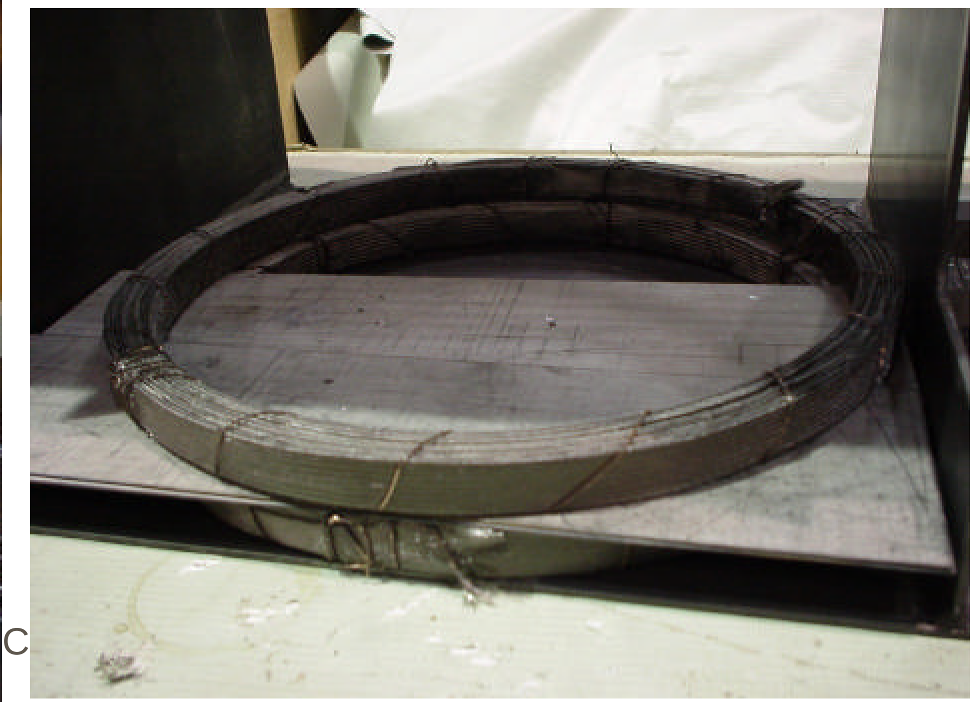




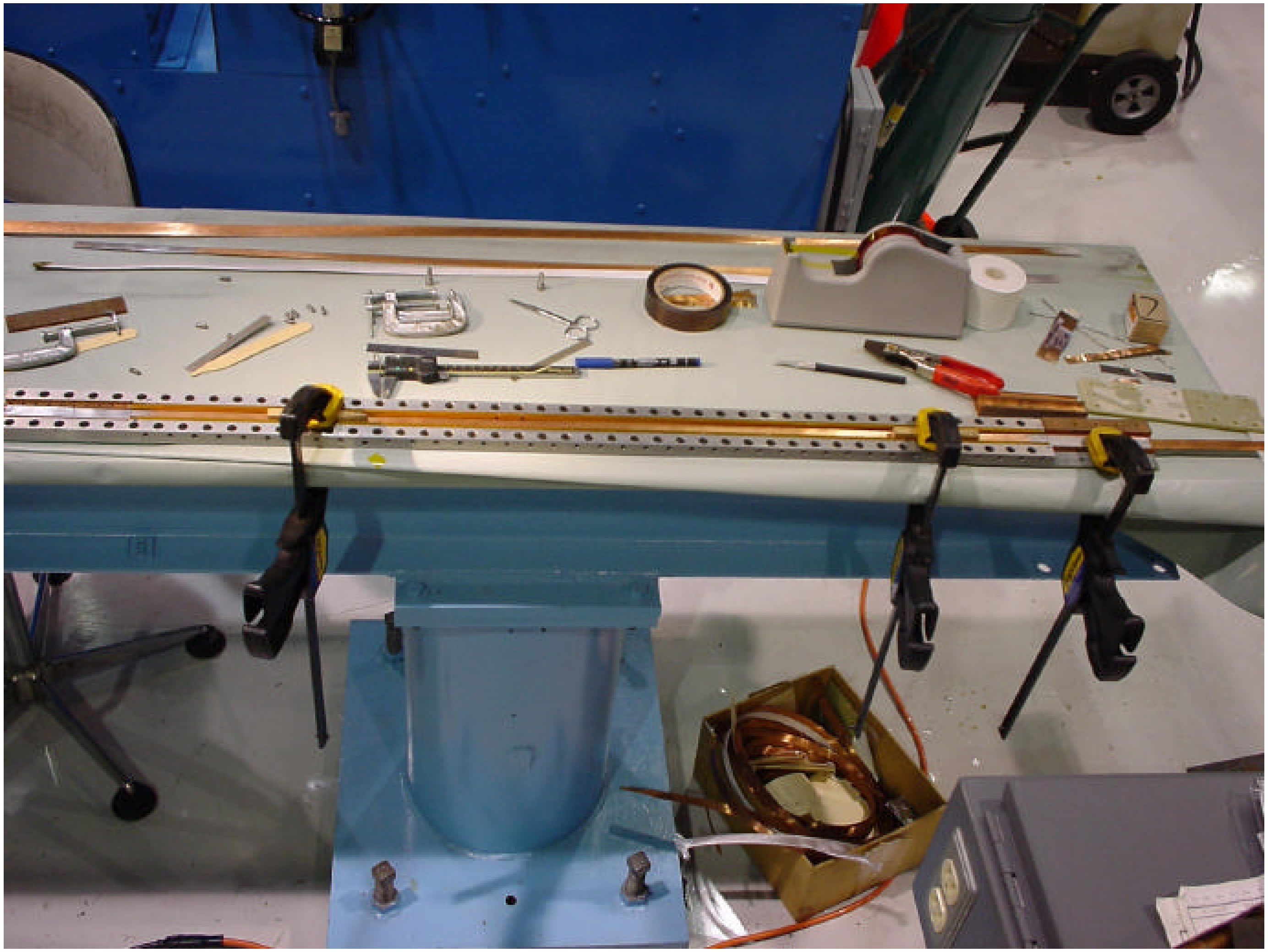
- Strands:
  - Ic degradation of wires measured using Fermilab ss-test facility,



C

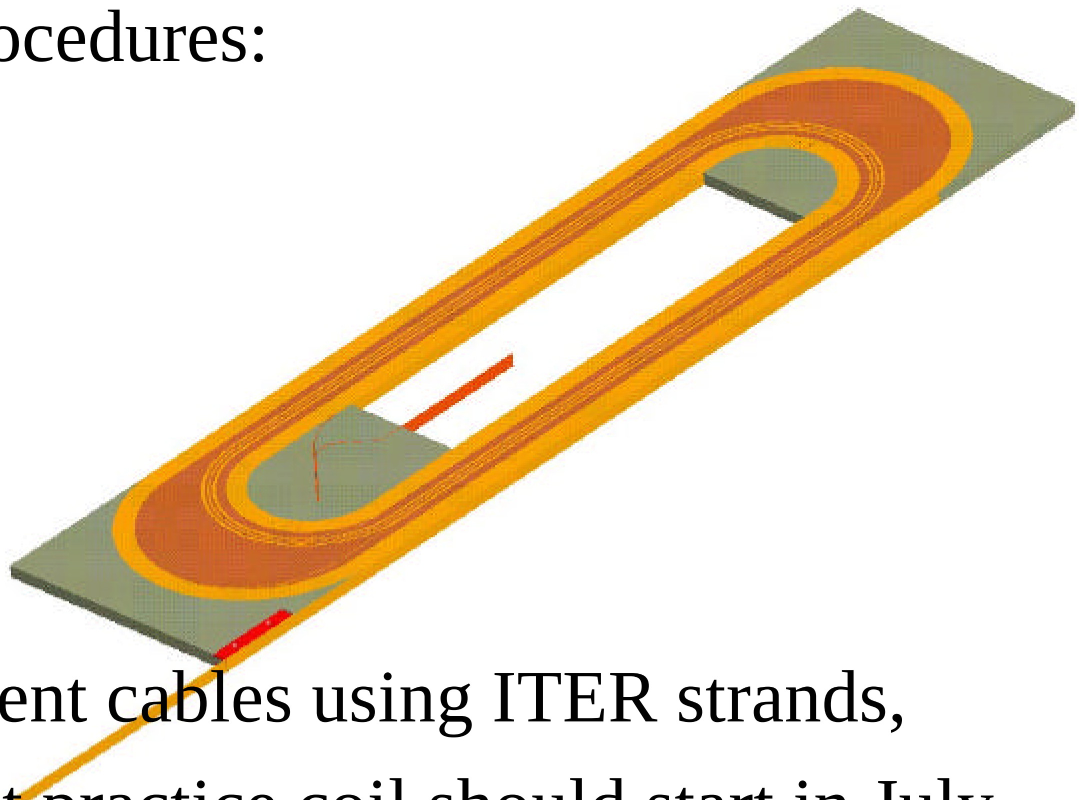


Cable sample holder assembling



Practice coils

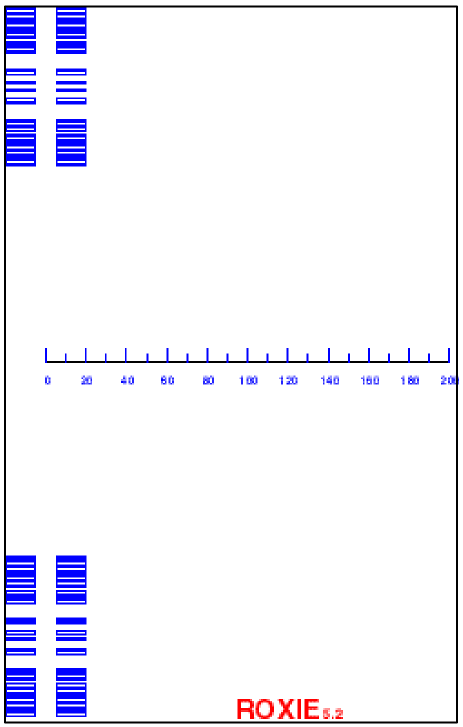
- Practice coils will be produced in order to develop all assembling procedures:
  - cable reaction,
  - insulation,
  - winding,
  - splices,
  - impregnation,

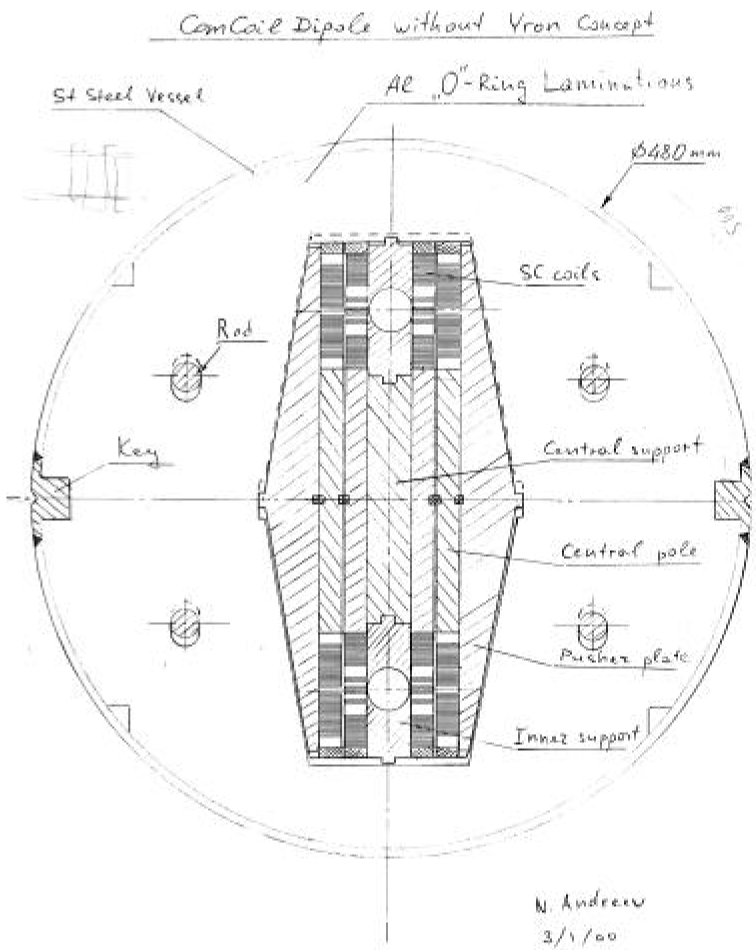


- Conductor: different cables using ITER strands,
- Production of first practice coil should start in July.

Coil test facility ??

- Simple mechanical structure to test 2 NbSn coils:
- 10 mm gap,
- 23 kA,
- 7.5 T





Status and plans

- First conceptual design is ready and alternative designs are under study.
- React-and-wind technology R&D is underway
- Goals for this year:
  - finalize mechanical design
  - select cable
  - fabricate test coils (start mid-June)
  - assemble a mechanical model (winter 00-01)
- Fabrication of the first short model is expected to start during spring 2001,
- Goal: test the first model in summer 2001.